Three-body correlations in direct reactions: Example of ^{6}Be populated in (p,n) reaction

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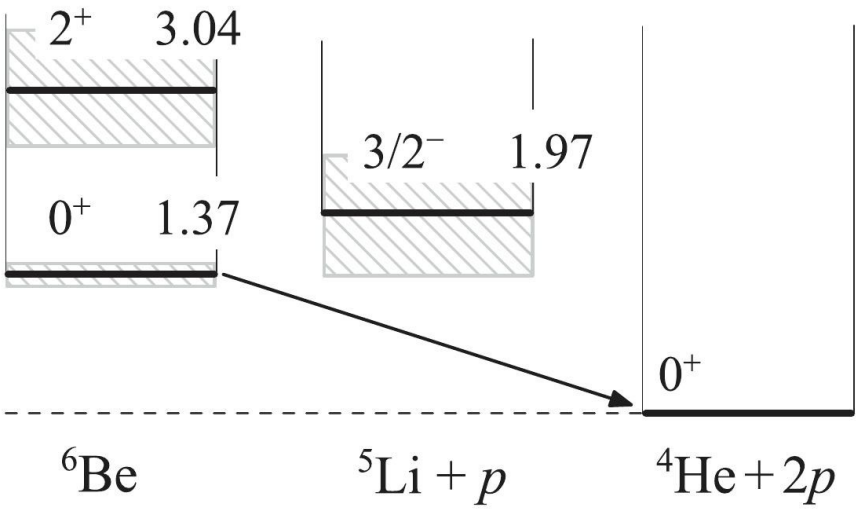
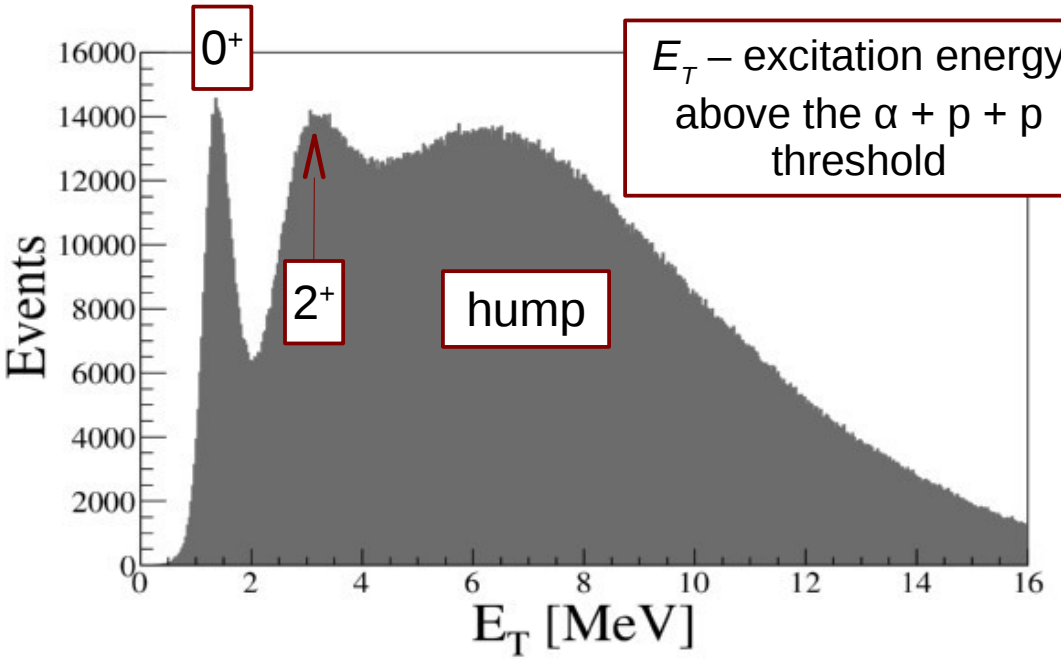
^{6}Be

- alpha core + 2 valence protons
- the lightest true 2p emitter
- information on correlations very limited

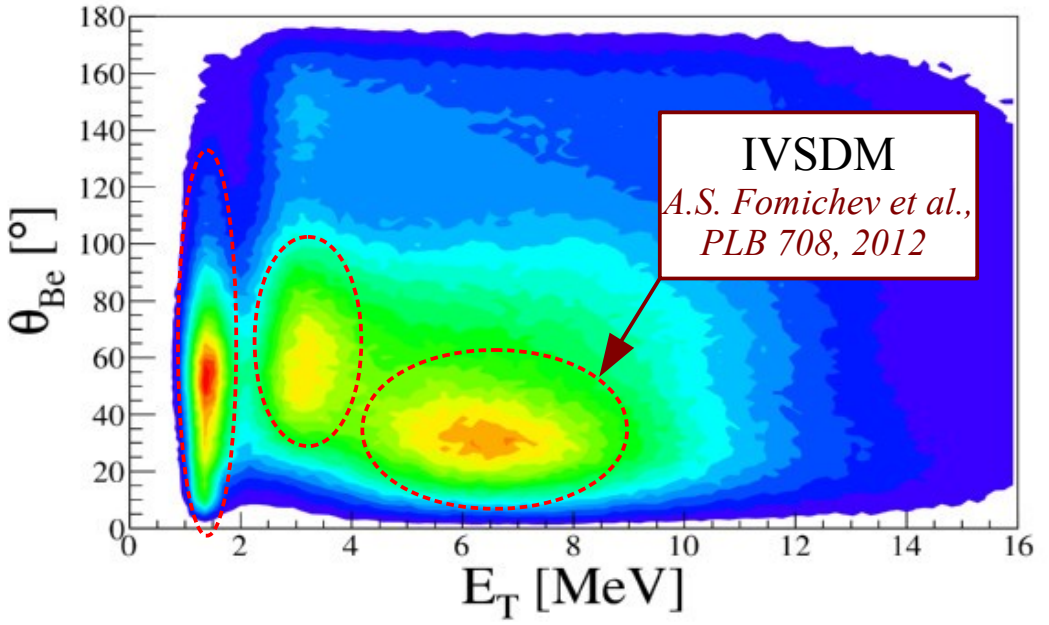


Introduction

$$^{6}\mathrm{Li} + \mathrm{p} \rightarrow {}^{6}\mathrm{Be} + \mathrm{n}$$
$$^{6}\mathrm{Be} \rightarrow \alpha + \mathrm{p} + \mathrm{p}$$



- 0^+, 2^+ states
- broad hump at $E_T > E_T(2^+)$



Theory used for data analysis

- combination of PWIA with Hyperspherical harmonics method
- differential cross section in density-matrix formalism

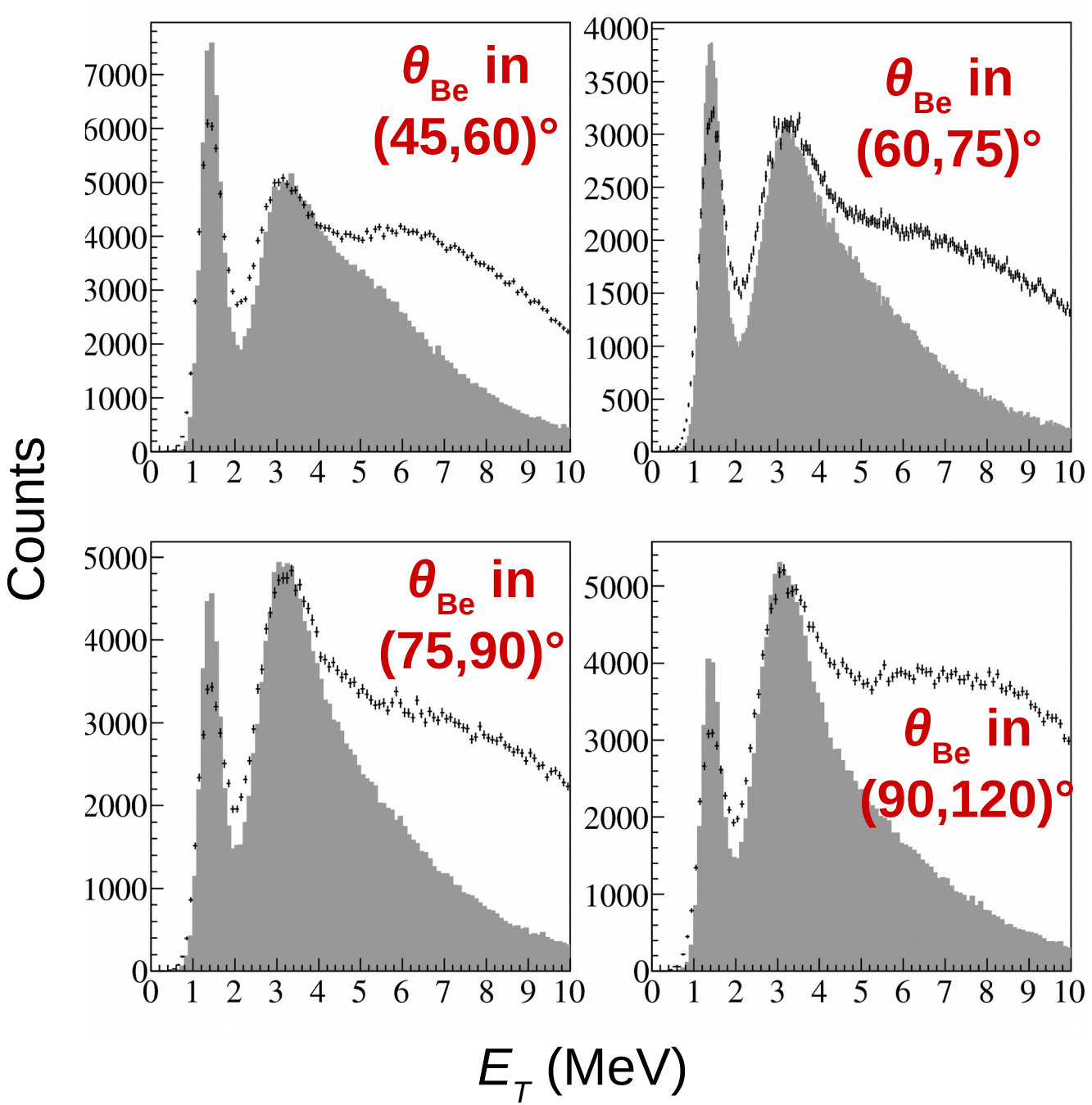
Parametrization of density matrix

$$\rho_{JM}^{J'M'} = \begin{pmatrix} \rho_{00}^{00} & & & \rho_{20}^{00} & & \\ & \rho_{22}^{22} & & & & \\ & & \rho_{21}^{21} & & & \\ \rho_{00}^{20} & & & \rho_{20}^{20} & & \\ & & & & \rho_{2-1}^{2-1} & \\ & & & & & \rho_{2-2}^{2-2} \end{pmatrix}$$

three free parameters:

- ratio of 0^+ and 2^+ states
- level of 2^+ alignment
- level of interference between 0^+ and 2^+

Invariant mass spectra fitting



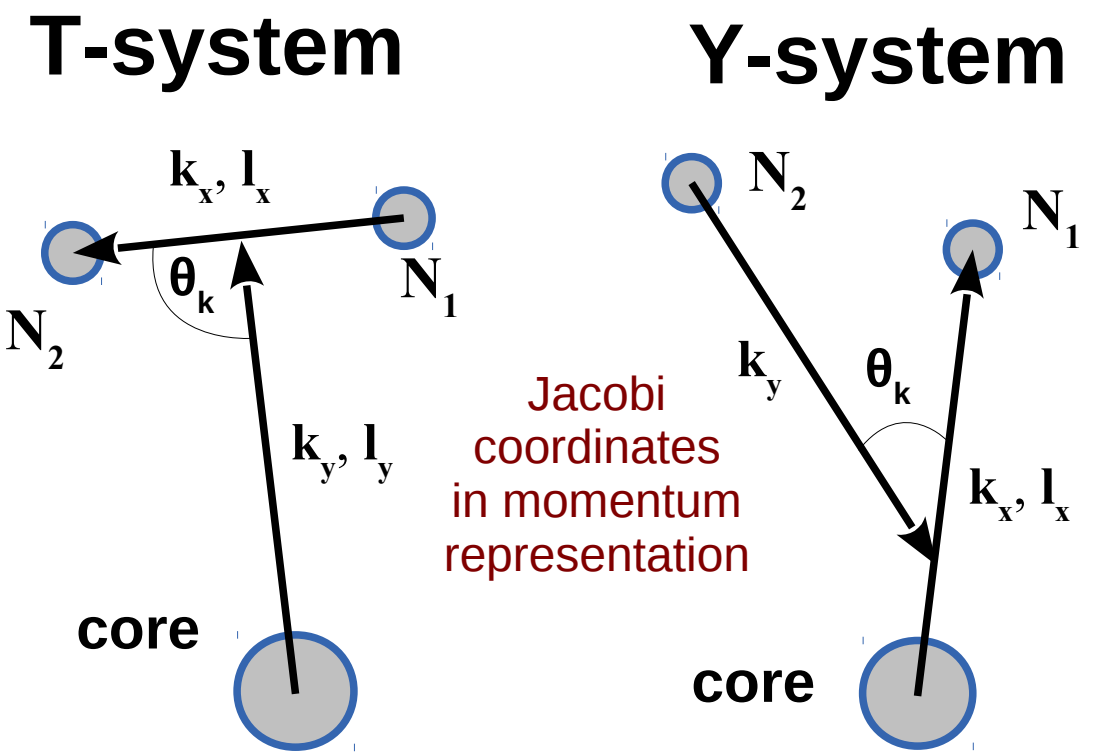
contribution of IVSDM not taken into account for MC

ratio of 0^+ and 2^+ states fixed

3-body internal correlation

2-body vs. 3-body decay

- 2 parameters for 2-body decay (E,Γ)
- 5 additional parameters at given energy for 3-body decay



3-body internal correlation

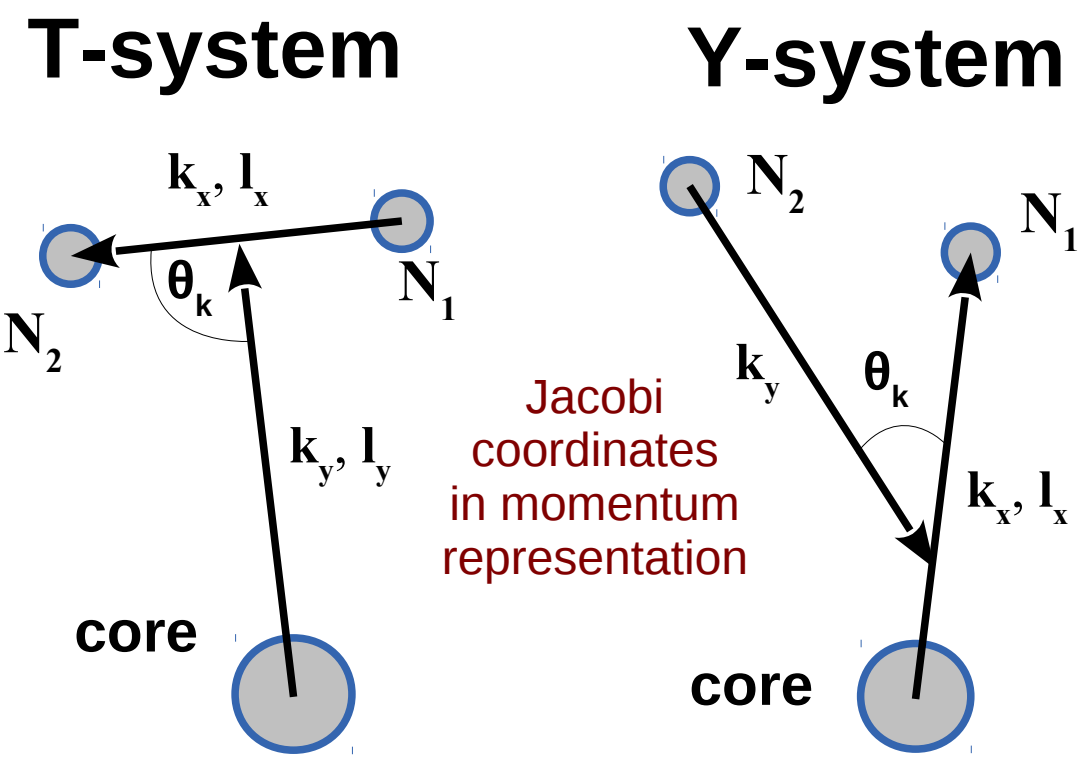
2-body vs. 3-body decay

- 2 parameters for 2-body decay (E,Γ)
- 5 additional parameters at given energy for 3-body decay

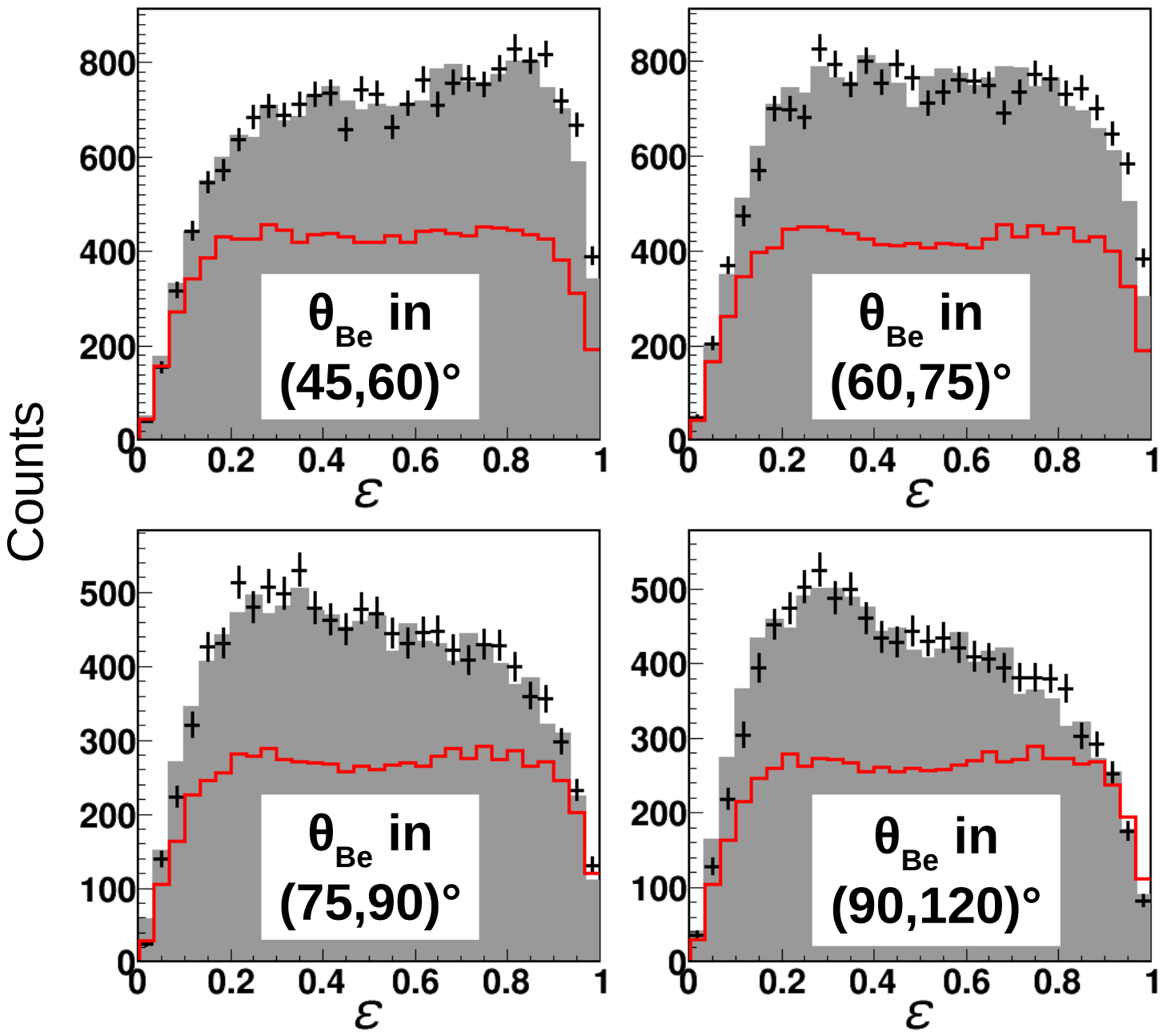
full description of the internal correlations by parameters ε and θ_k

$$\varepsilon = \frac{E_x}{E_x + E_y}$$

$$\cos\theta_k = \frac{\mathbf{k}_x \cdot \mathbf{k}_y}{k_x k_y}$$



Test on ground state



E_T<1.4 MeV

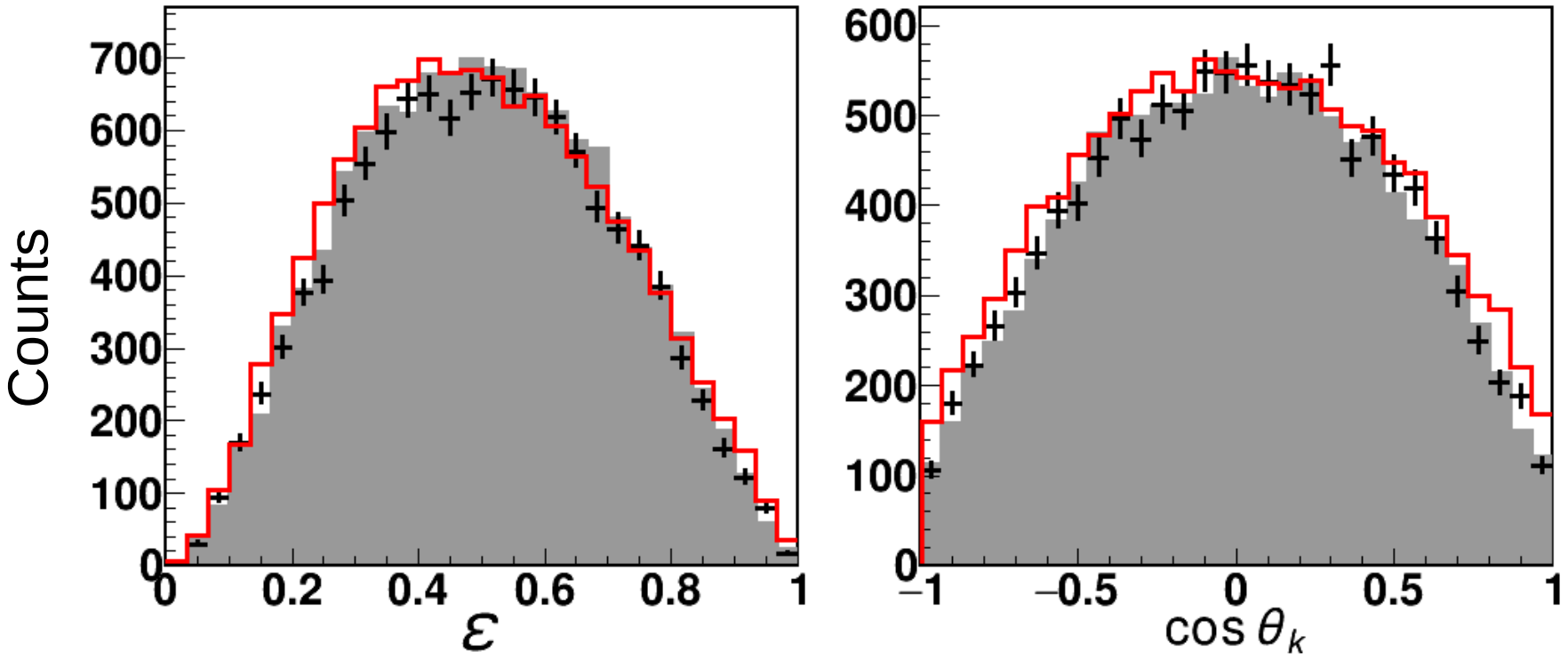
no free parameters!!!

experiment

MC simulation

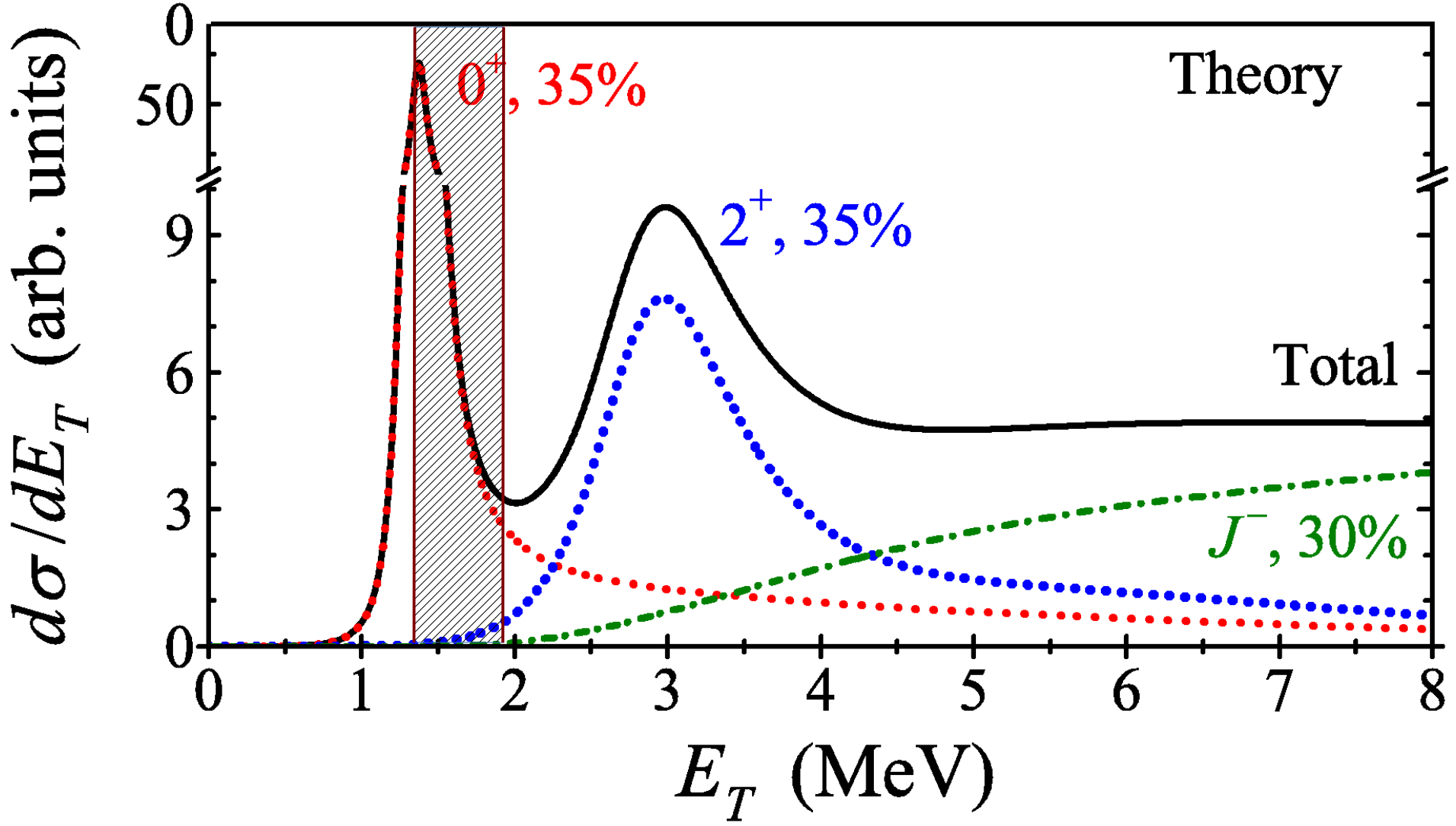
theoretical input

Test on ground state

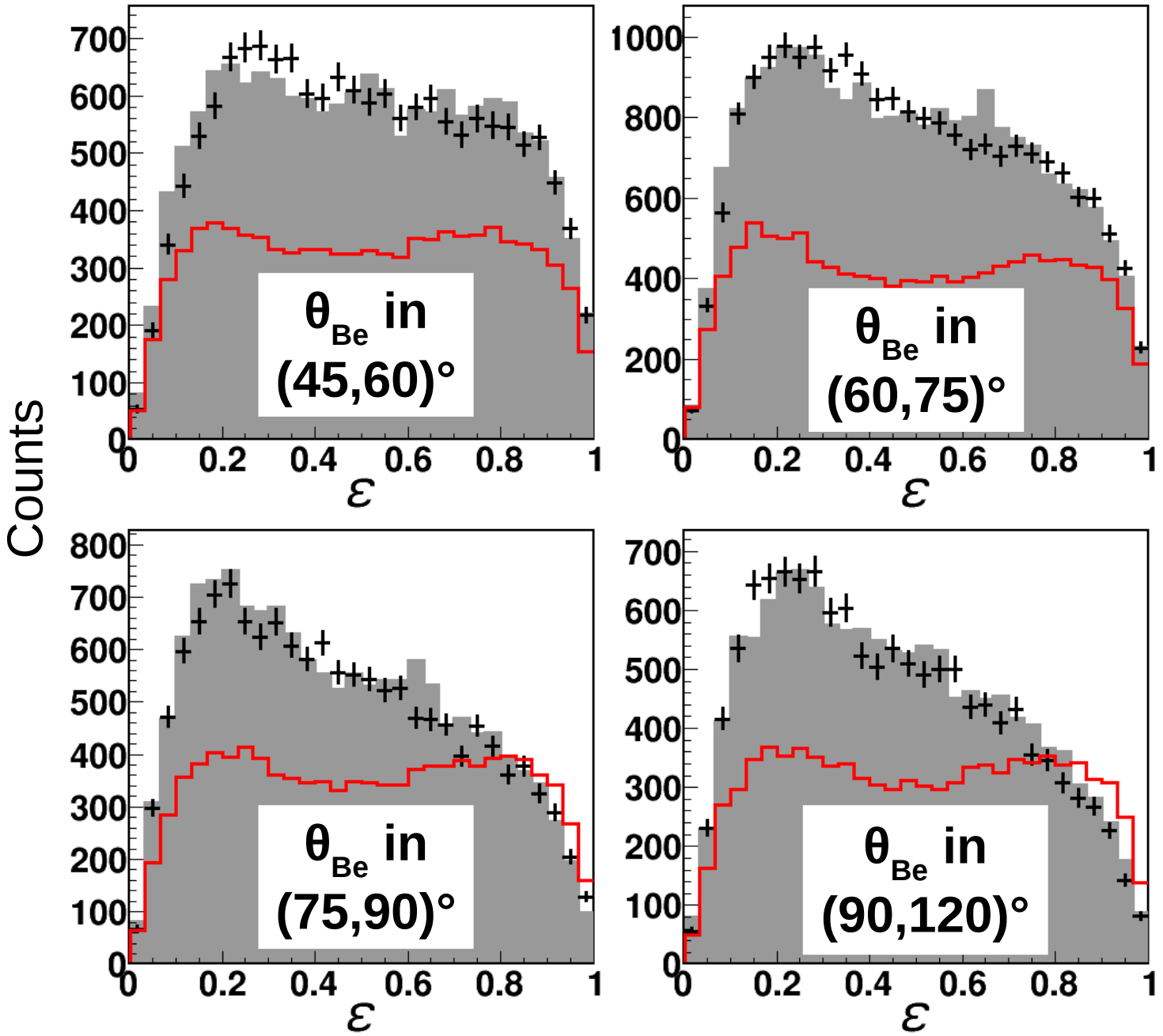


- well working theoretical model
- efficiency taken into account in correct way

Left slope of ground state



Left slope of ground state



E_T in (1.4,1.9) MeV

presence of 2^+

two free parameters remained:

interference of 0^+ and 2^+

alignment of 2^+

Internal correlations

1.4 < E_T < 1.9 MeV; θ_{Be} in (75,90) deg; T-system

2^+ aligned

2^+ non-aligned

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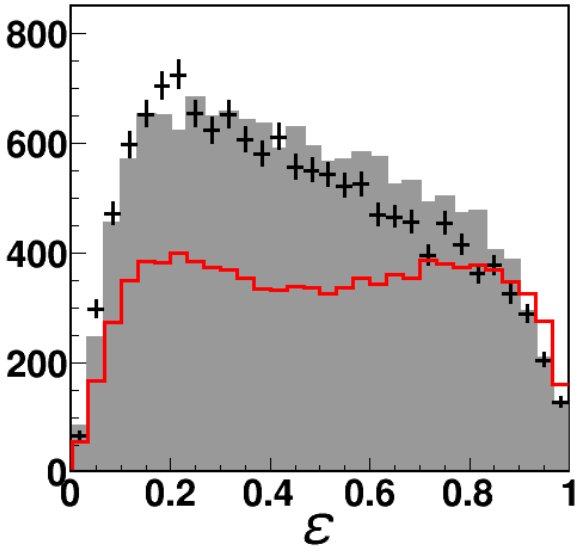
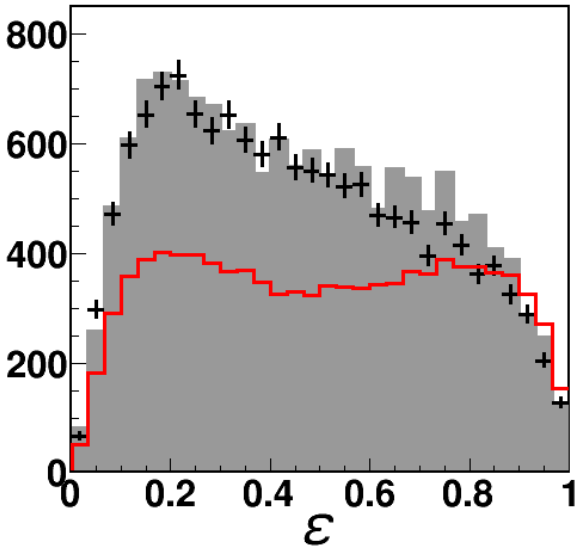


Counts

2^+ non-aligned

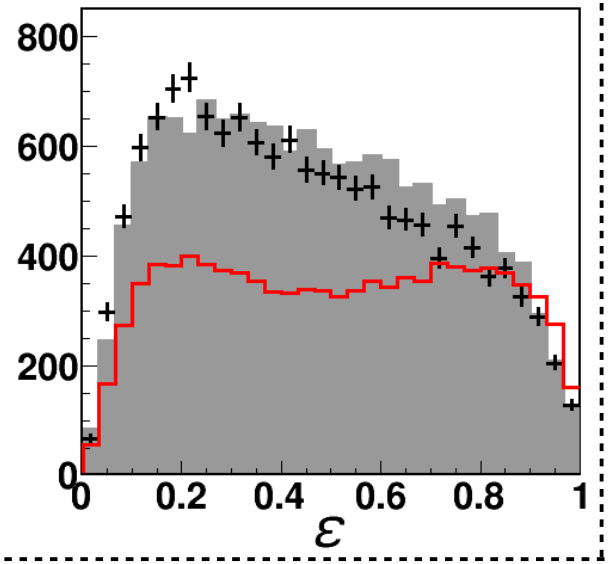


Internal correlations

1.4 < E_T < 1.9 MeV; θ_{Be} in (75,90) deg; T-system

constructive | **incoherent** | **destructive**

2^+ aligned



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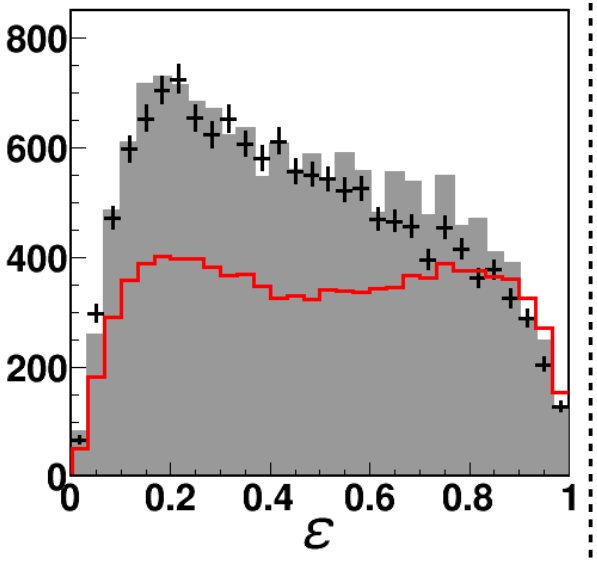

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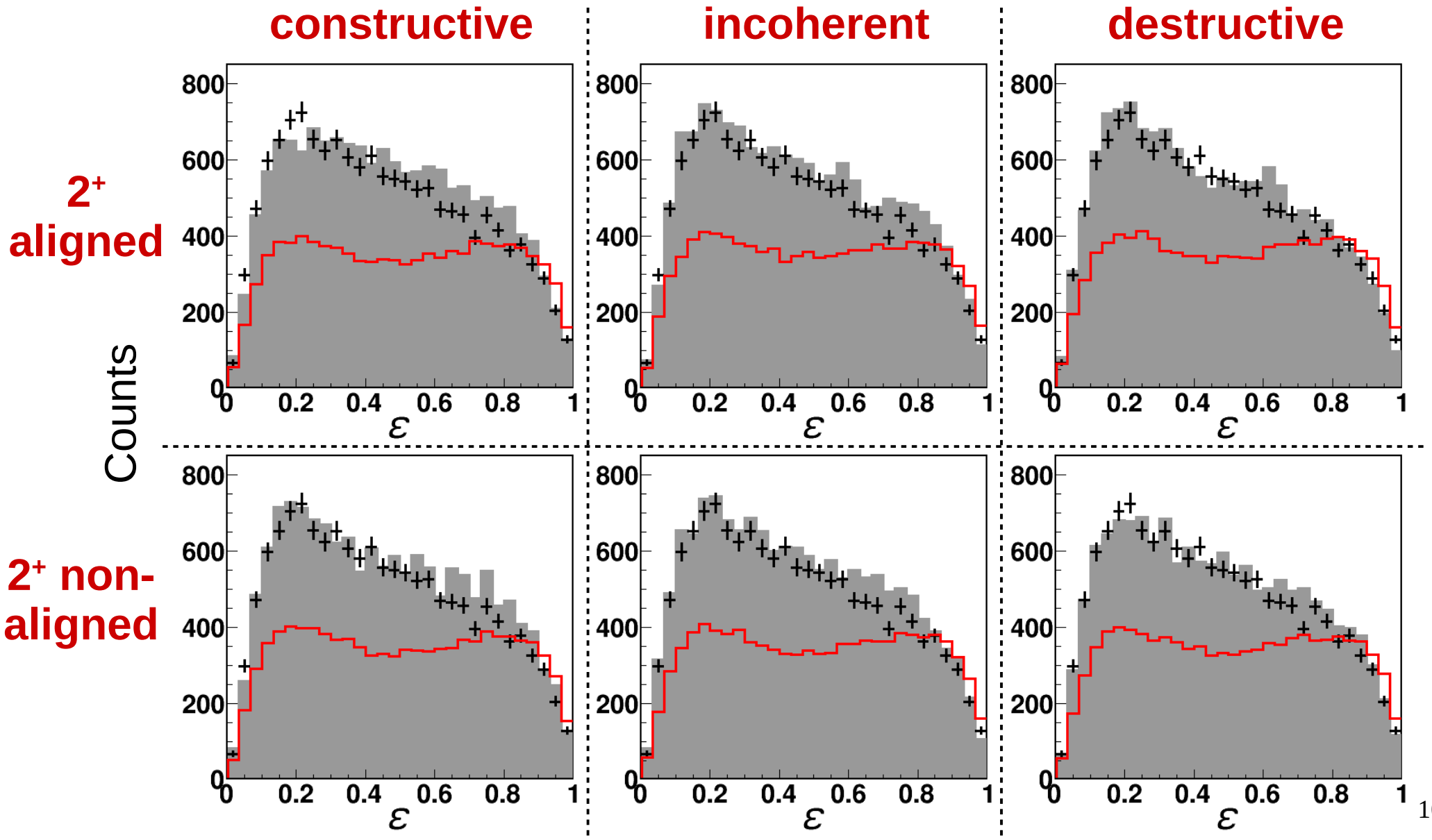
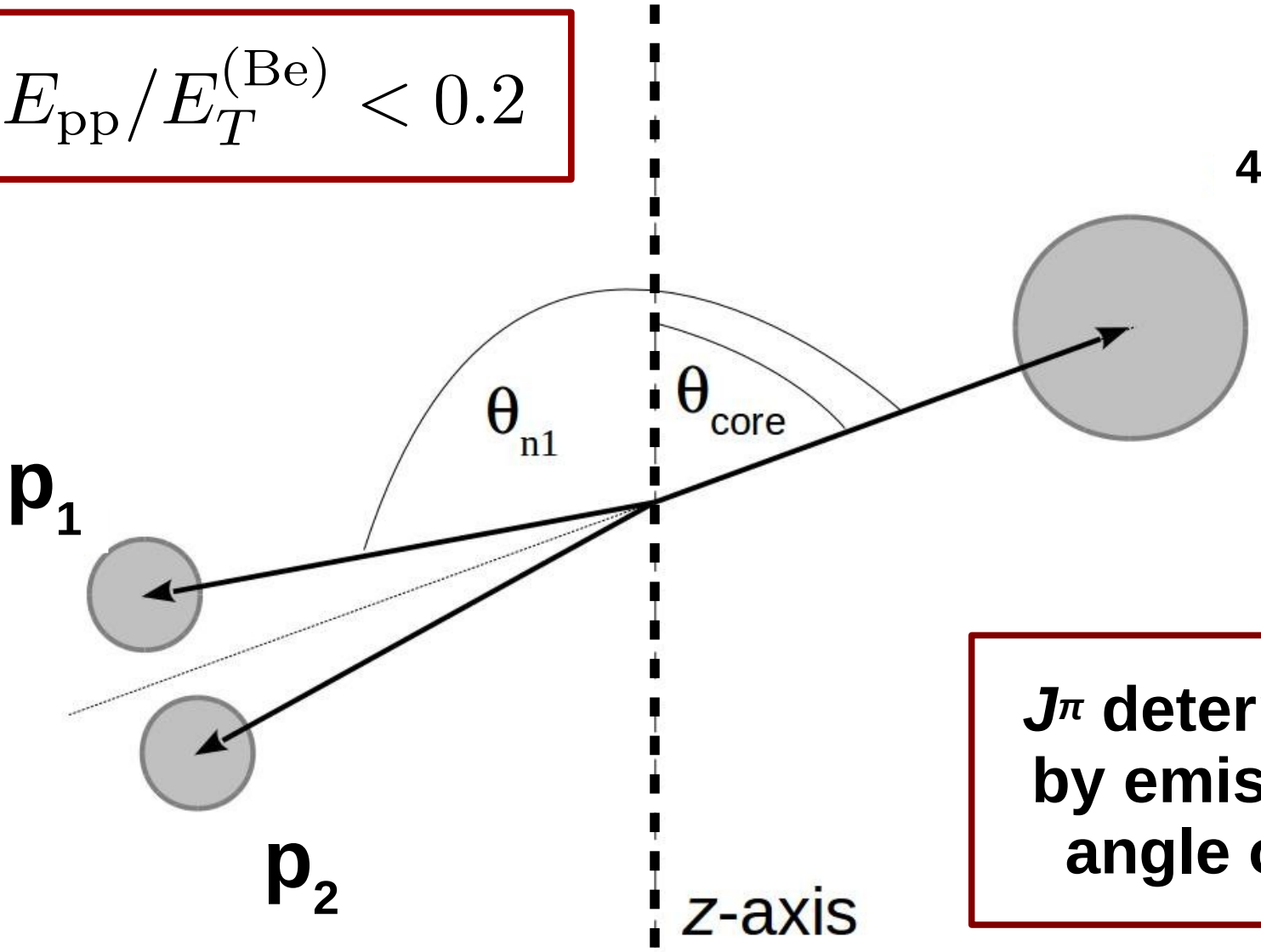


External correlations

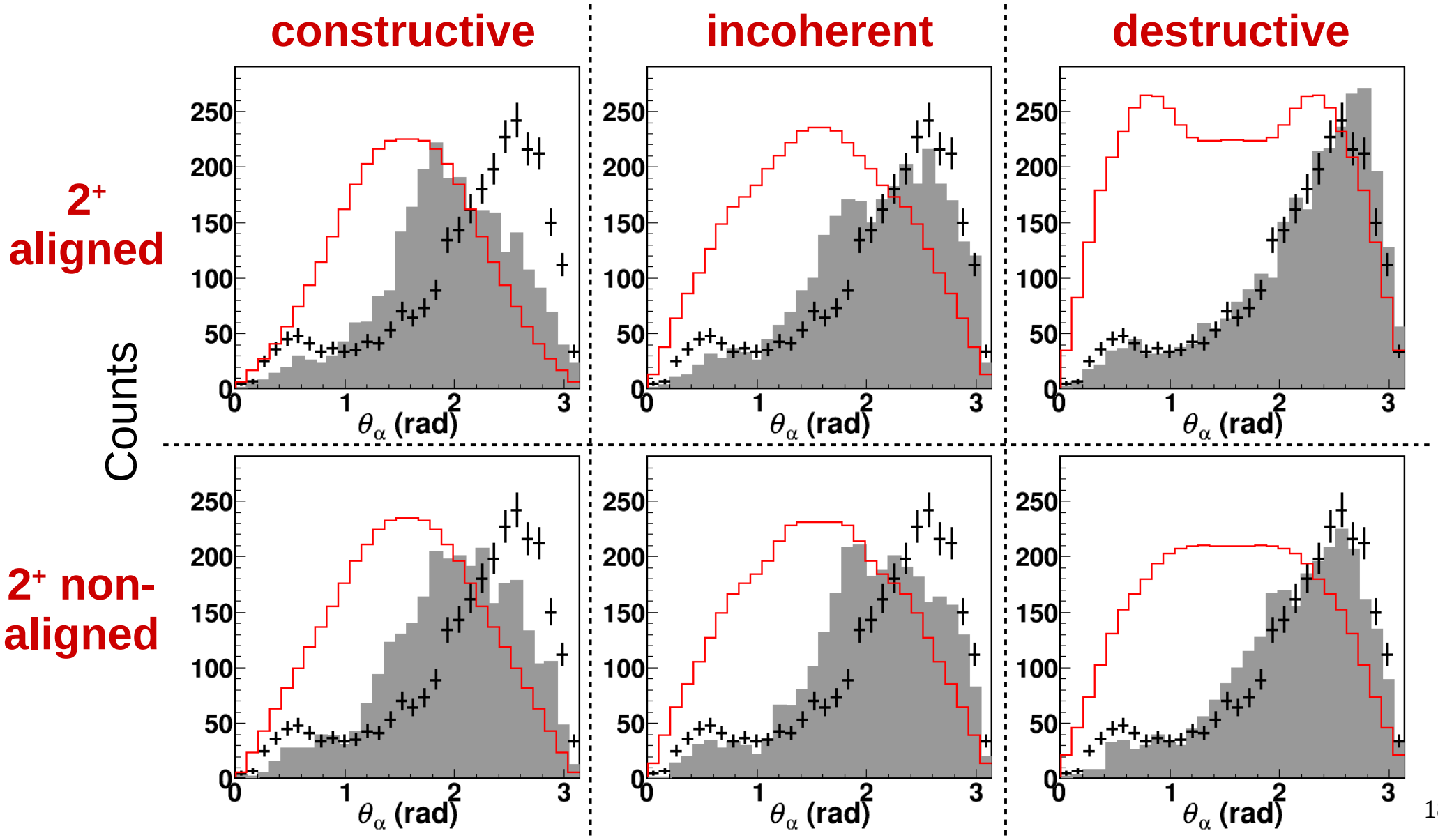
$$\varepsilon = E_{\rm pp}/E_T^{\rm (Be)} < 0.2$$



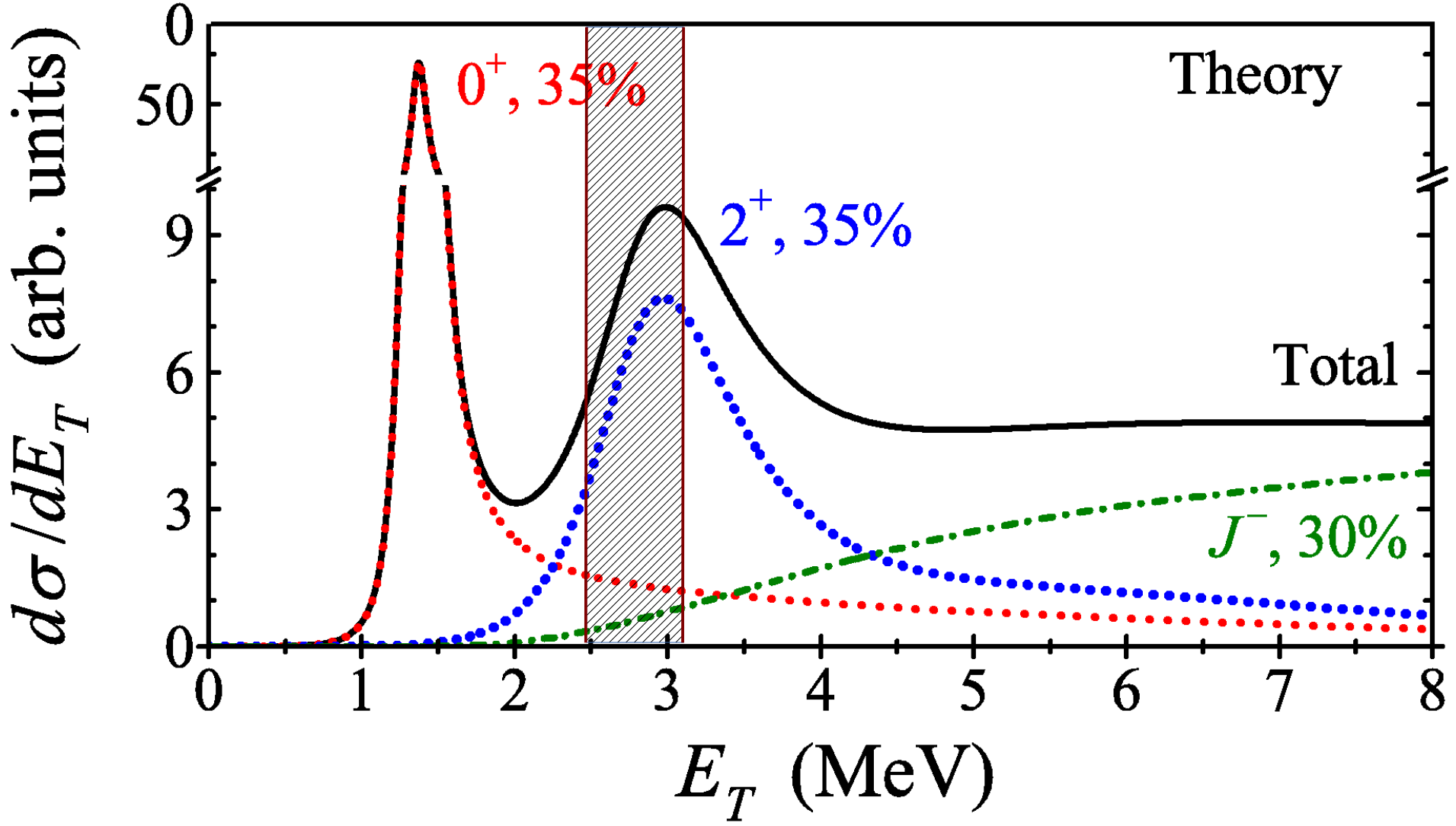
$J\pi$ determined by emission angle of α

External correlations

1.4 < E_T < 1.9 MeV; θ_{Be} in (75,90) deg;

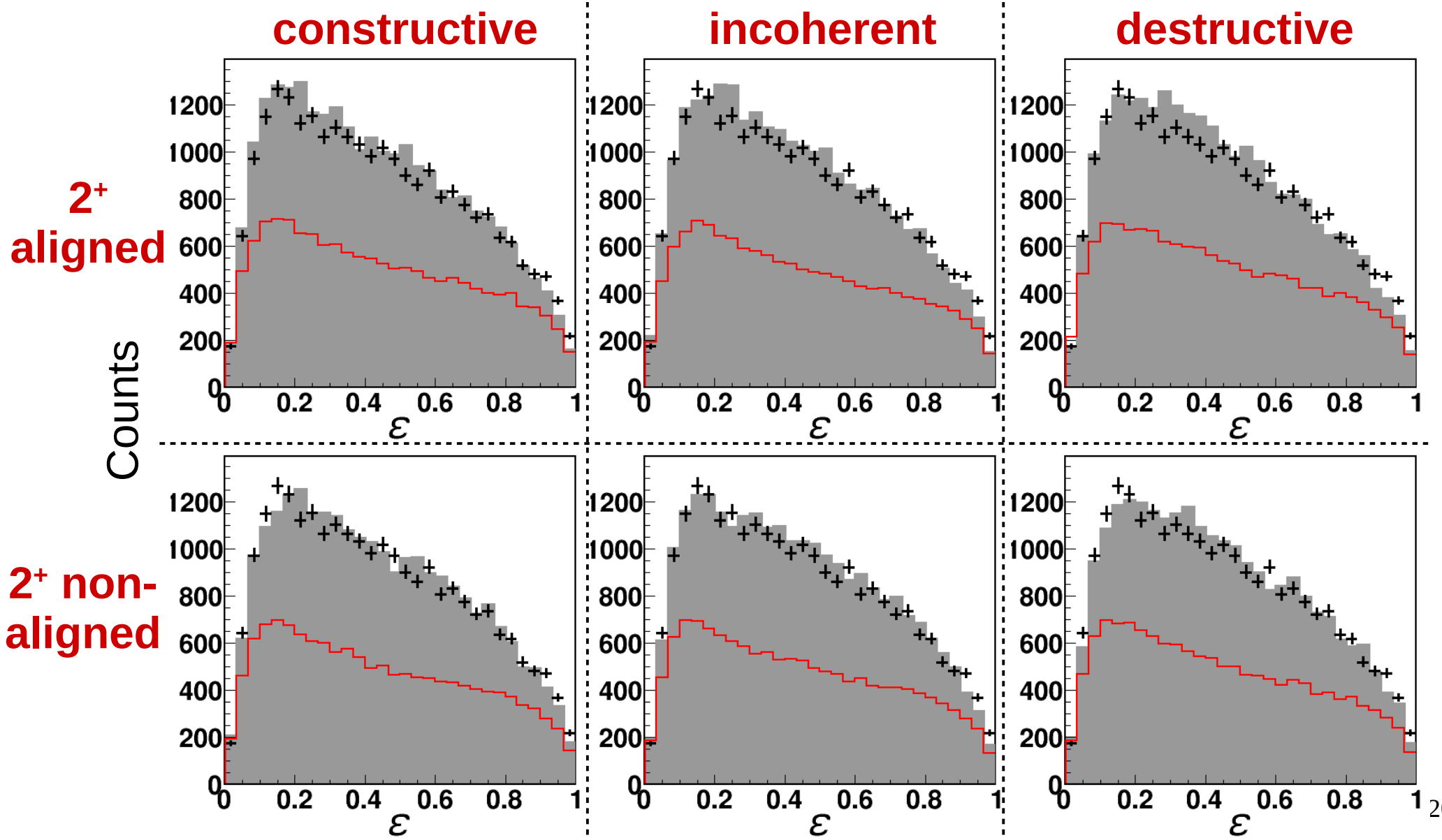


Right slope of 2^+



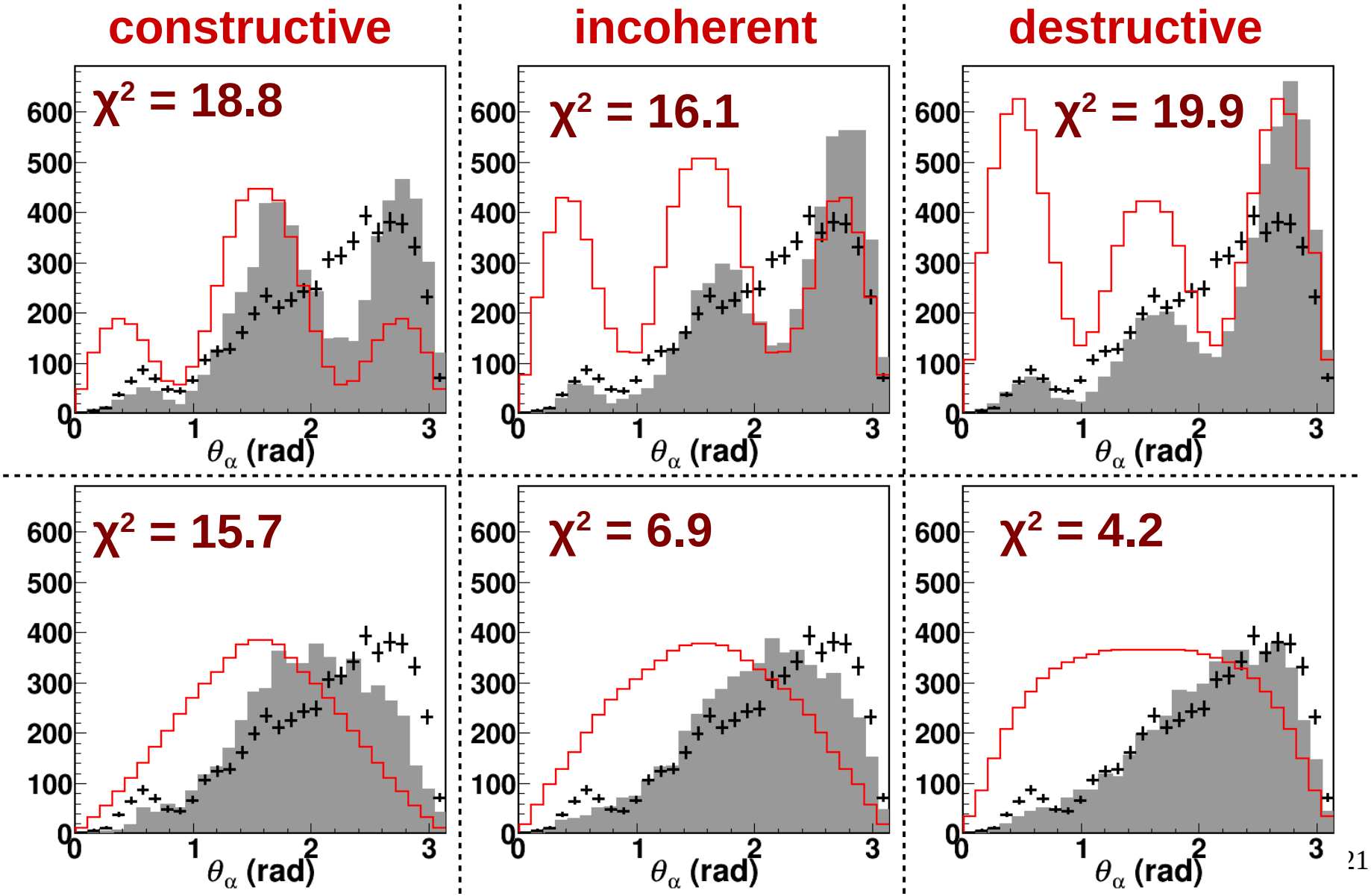
Right slope of 2^+: ε_T comparison

$2.5 < E_T < 3.1$ MeV; θ_{Be} in (75,90) deg; T-system



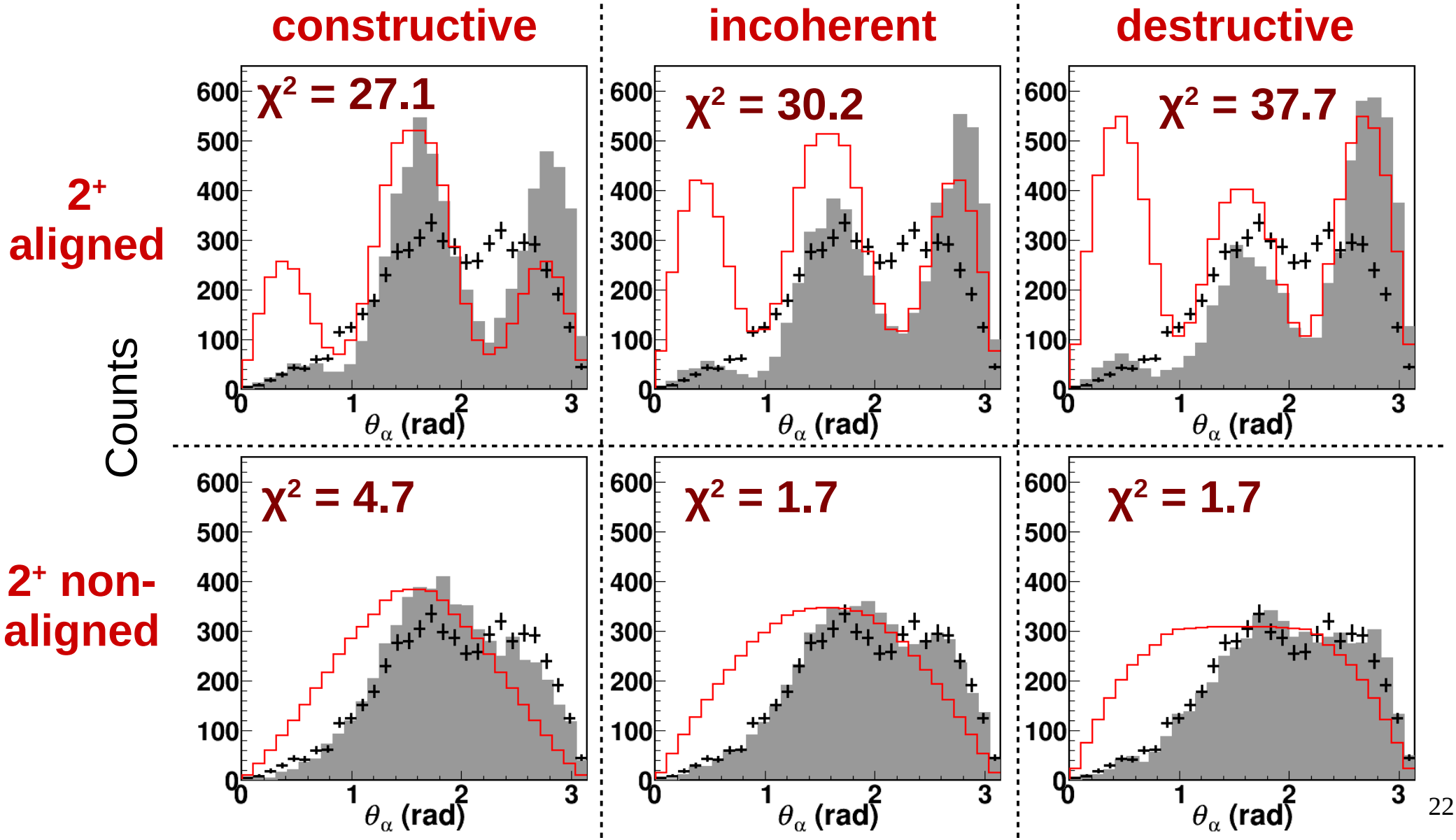
Right slope of 2^+: θ_α comparison

$2.5 < E_T < 3.1$ MeV; θ_{Be} in (75,90) deg;

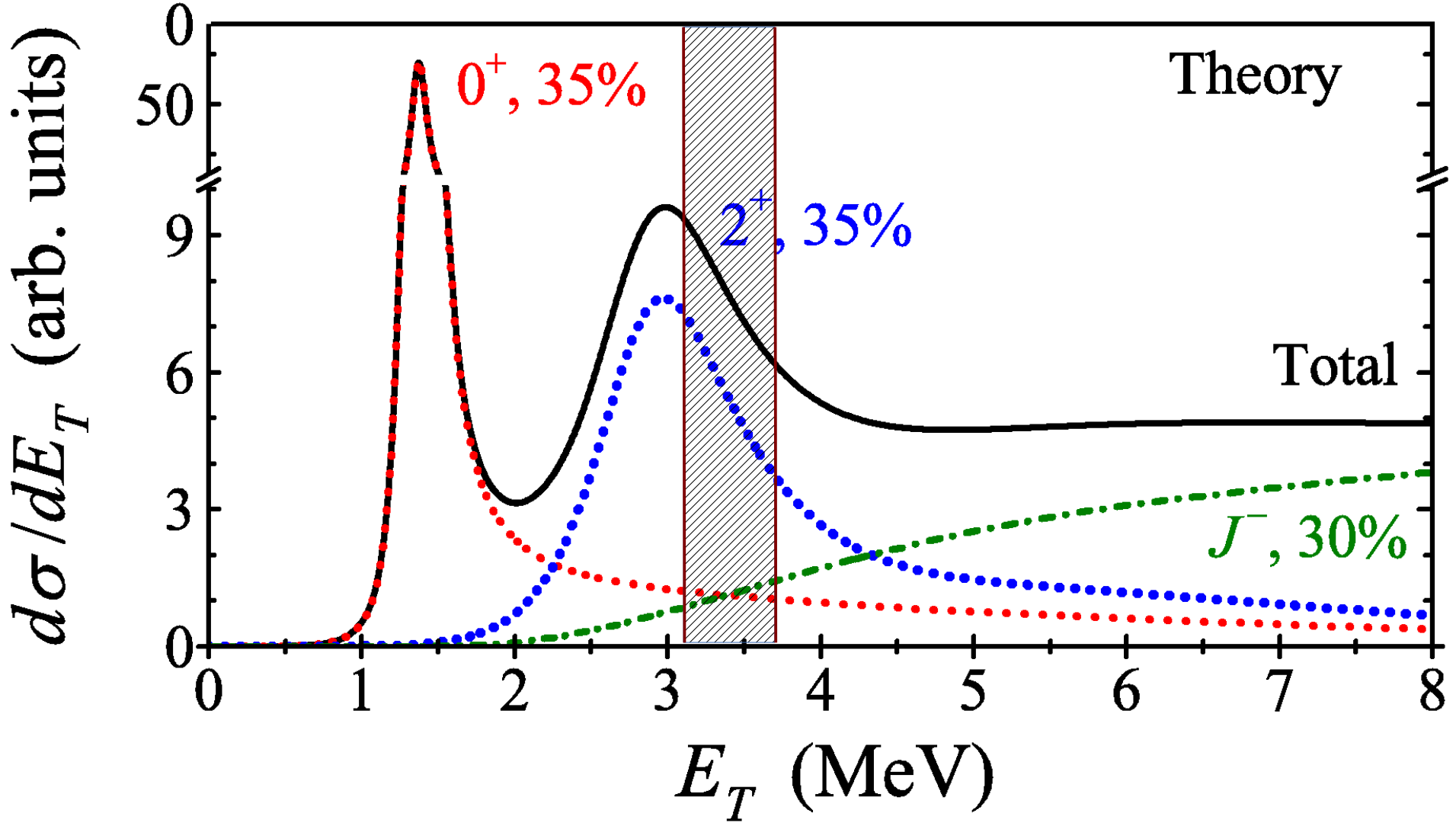


Right slope of 2^+: θ_α comparison

$2.5 < E_T < 3.1$ MeV; θ_{Be} in (90,120) deg;

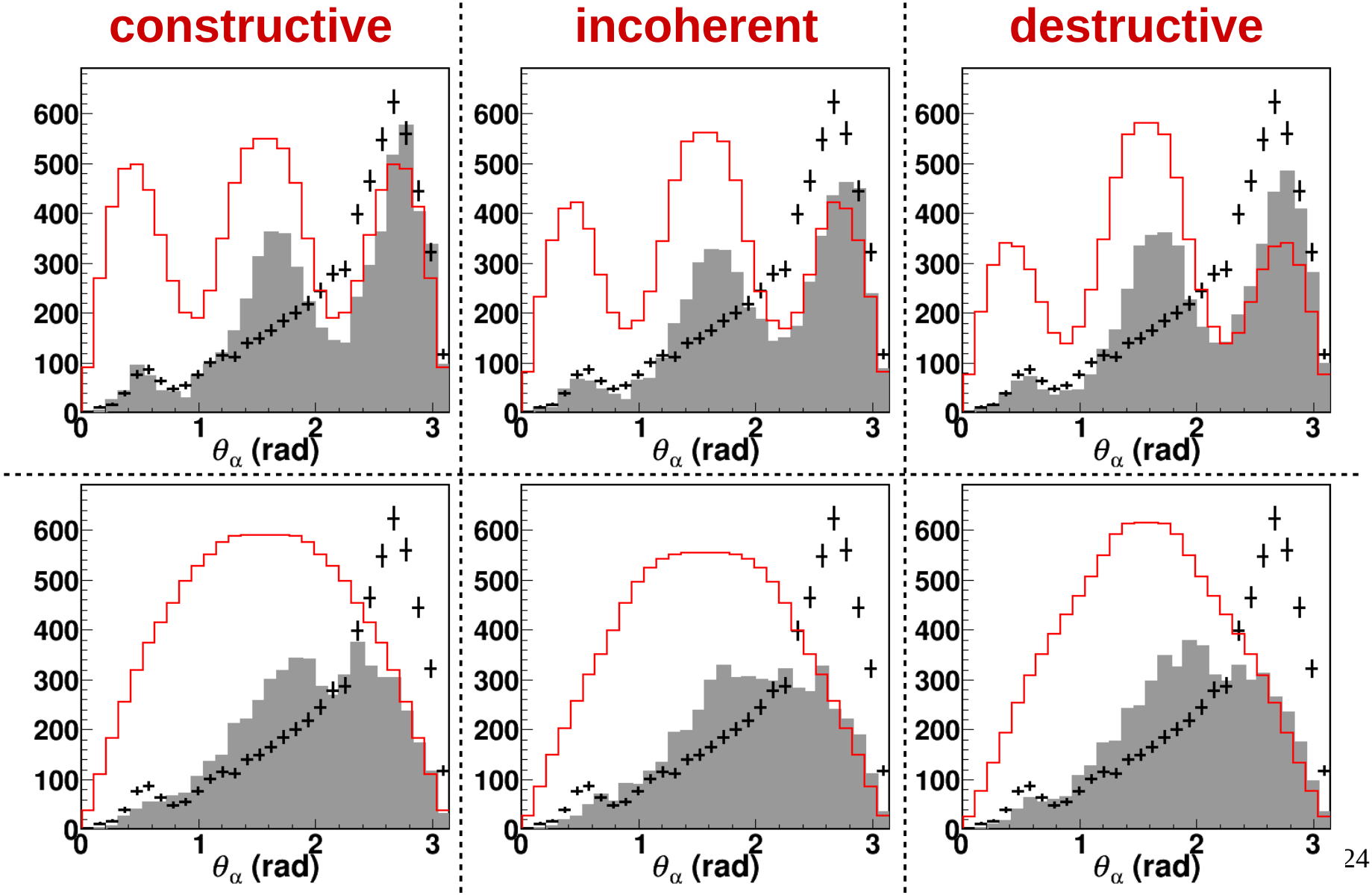


Beyond the 2^+ maximum

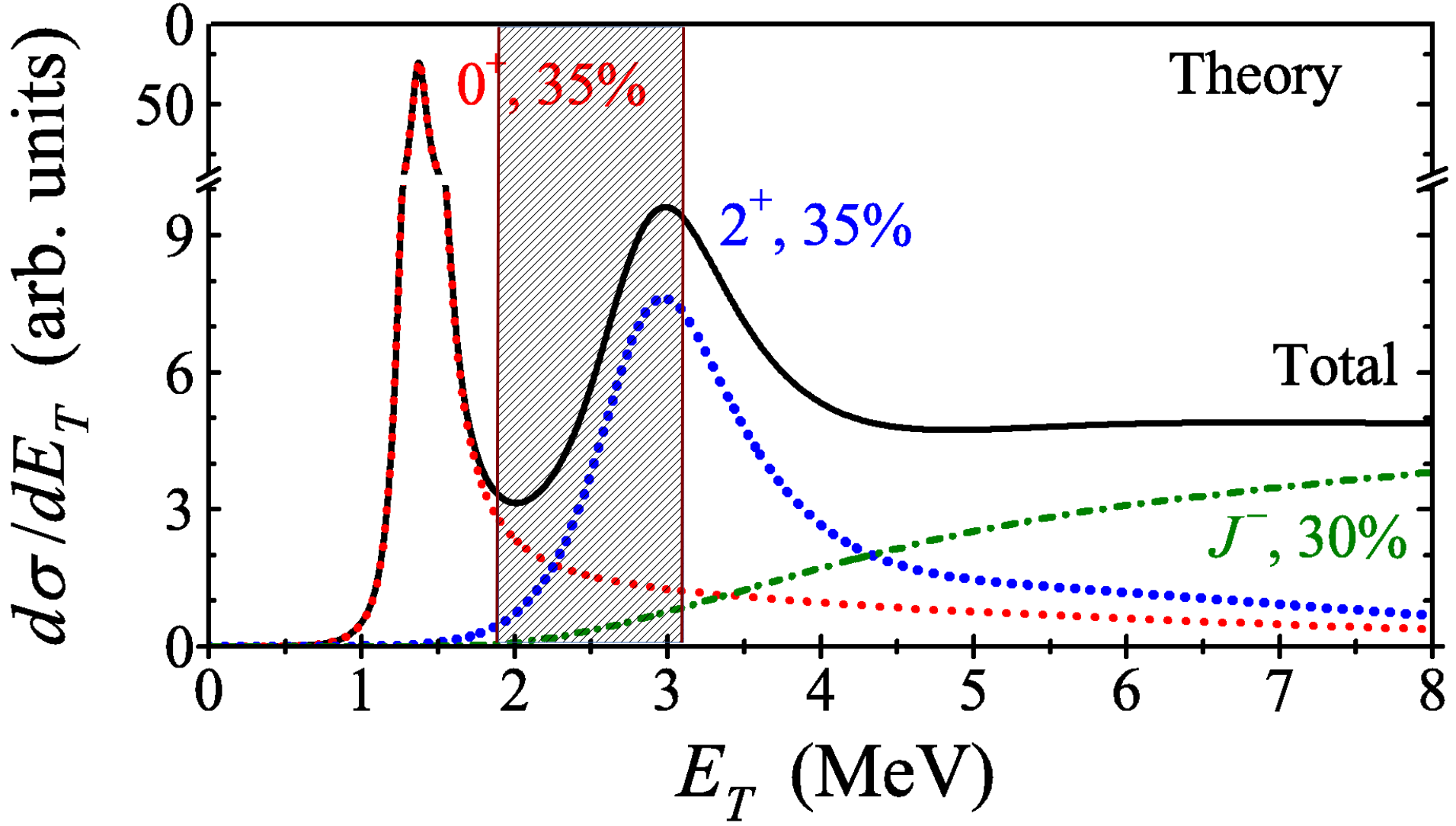


Beyond the 2^+ maximum

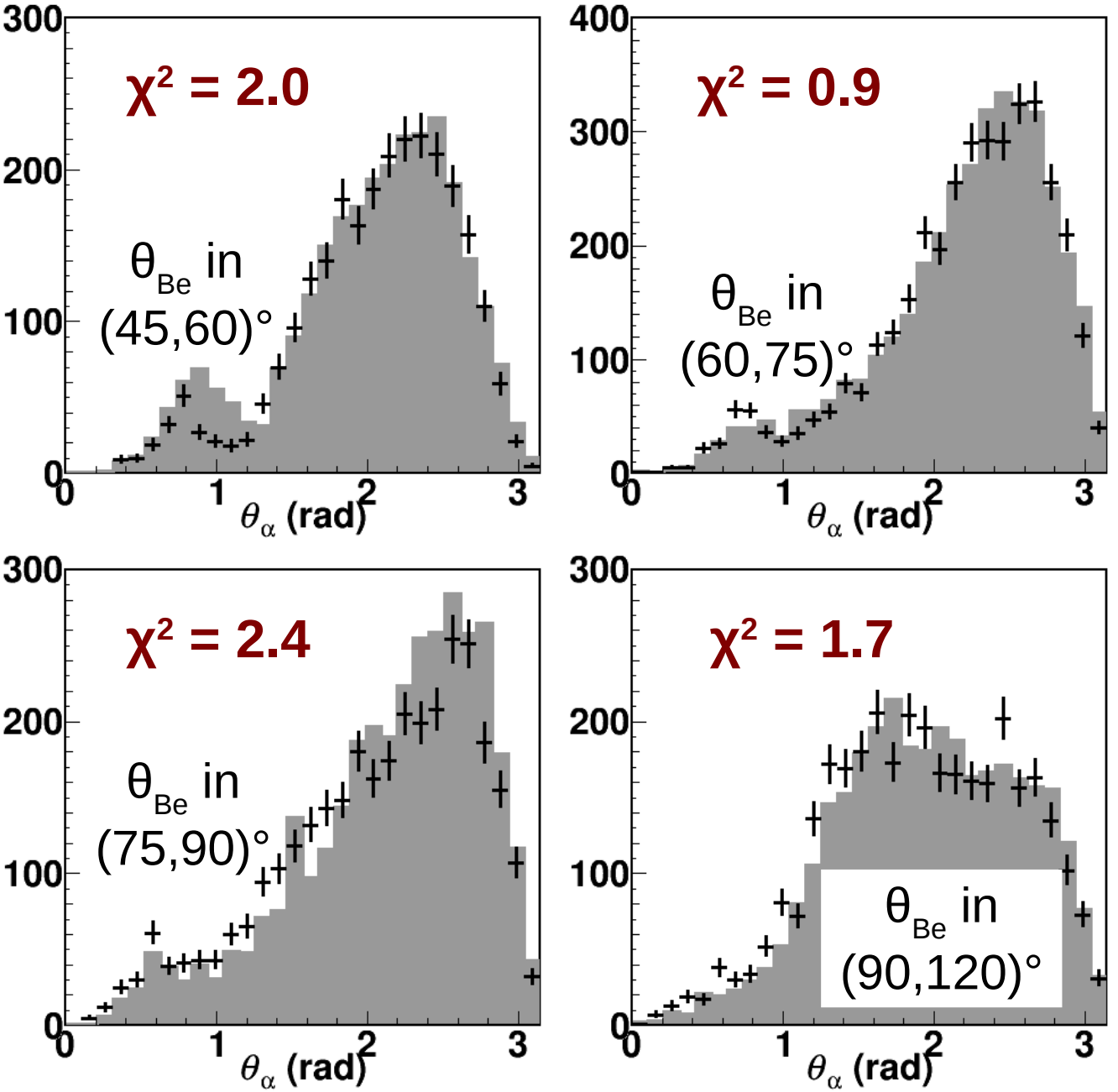
3.1 < E_T < 3.7 MeV; θ_{Be} in (75,90) deg;



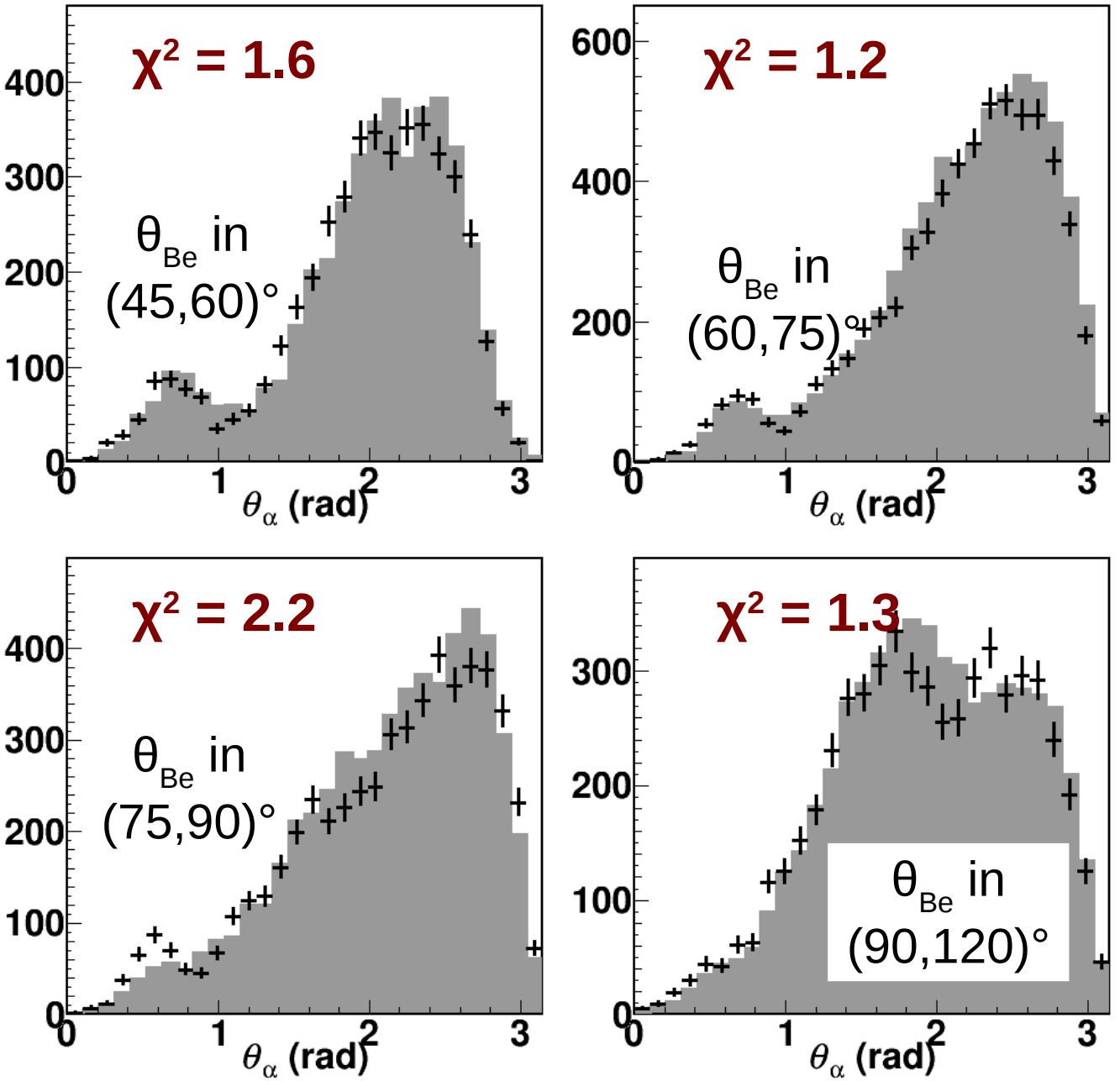
Left slope of 2^+



Best fits: 1.9 < E_T < 2.5 MeV



Best fits: 2.5 < E_T < 3.1 MeV



Conclusion

- IM spectrum populated in ^{6}Li(p,n)^{6}Be analyzed for $E_T < 3$ MeV
- internal structure of 3-body continuum with overlapping states may be revealed in correlations
- method may become a general tool for determination of fine effects of reaction mechanism

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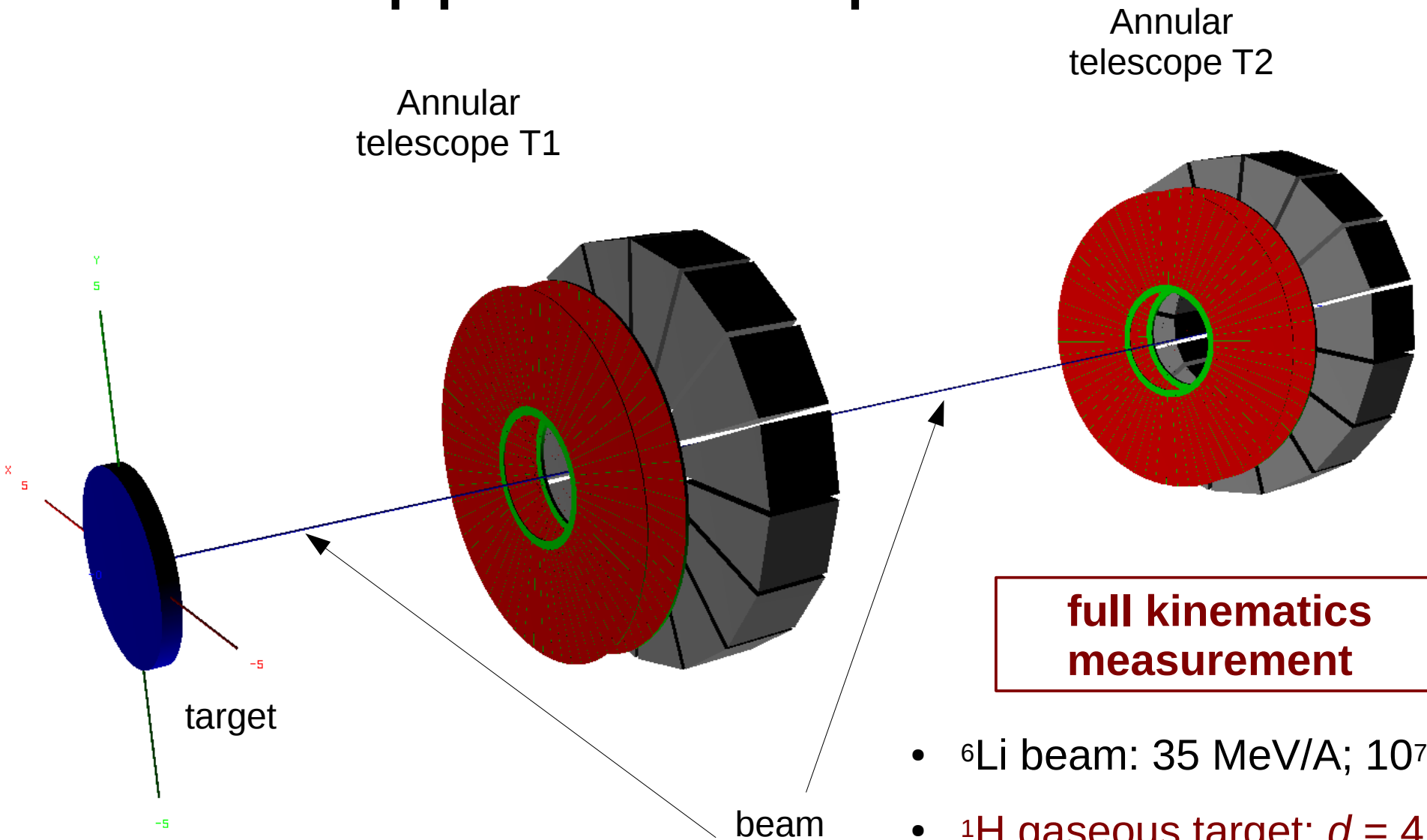
- IM spectrum populated in ^{6}Li(p,n)^{6}Be analyzed for $E_T < 3$ MeV
- internal structure of 3-body continuum with overlapping states may be revealed in correlations
- method may become a general tool for determination of fine effects of reaction mechanism

Thank for attention

End

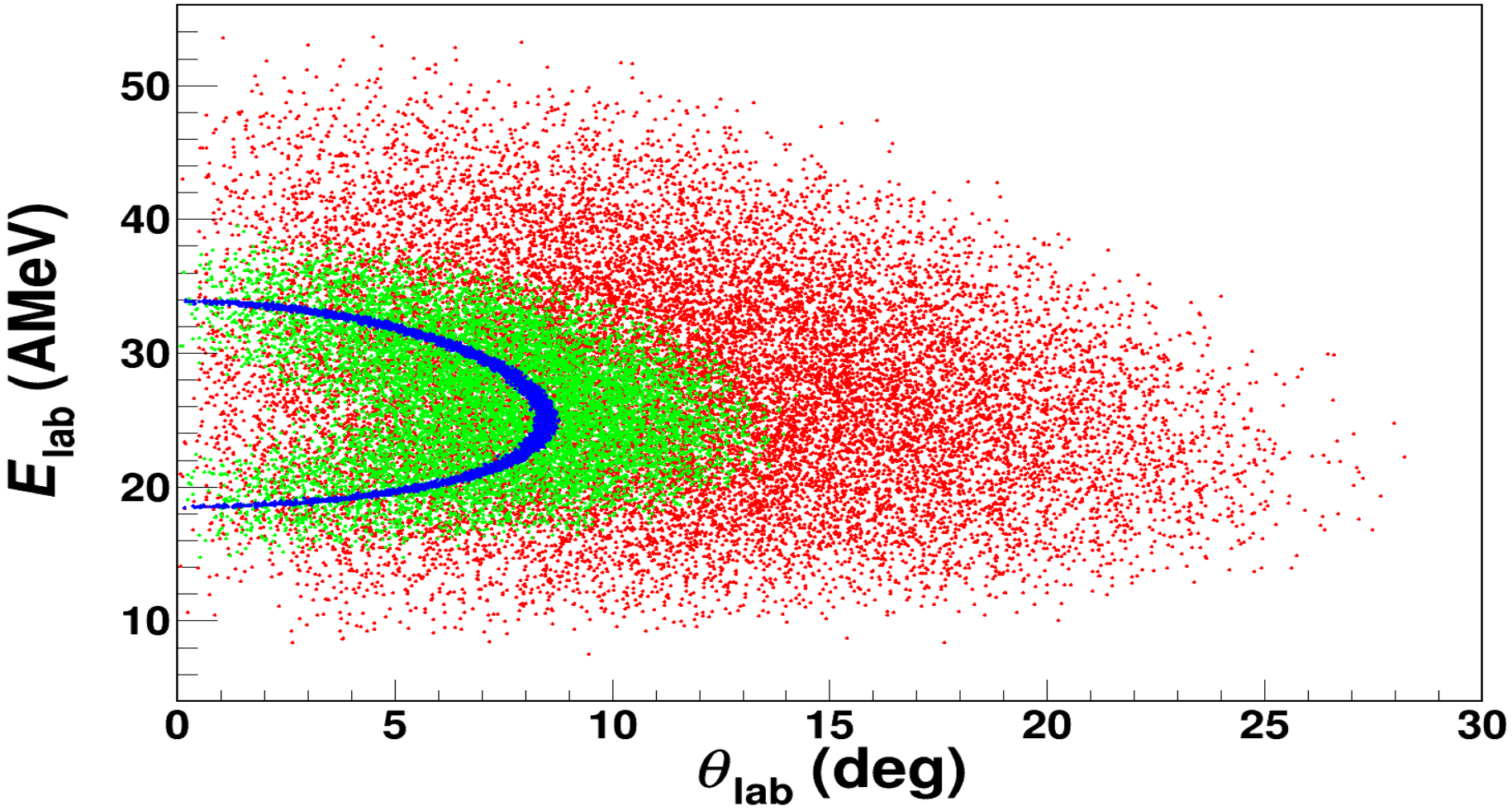
Appendix: Experiment



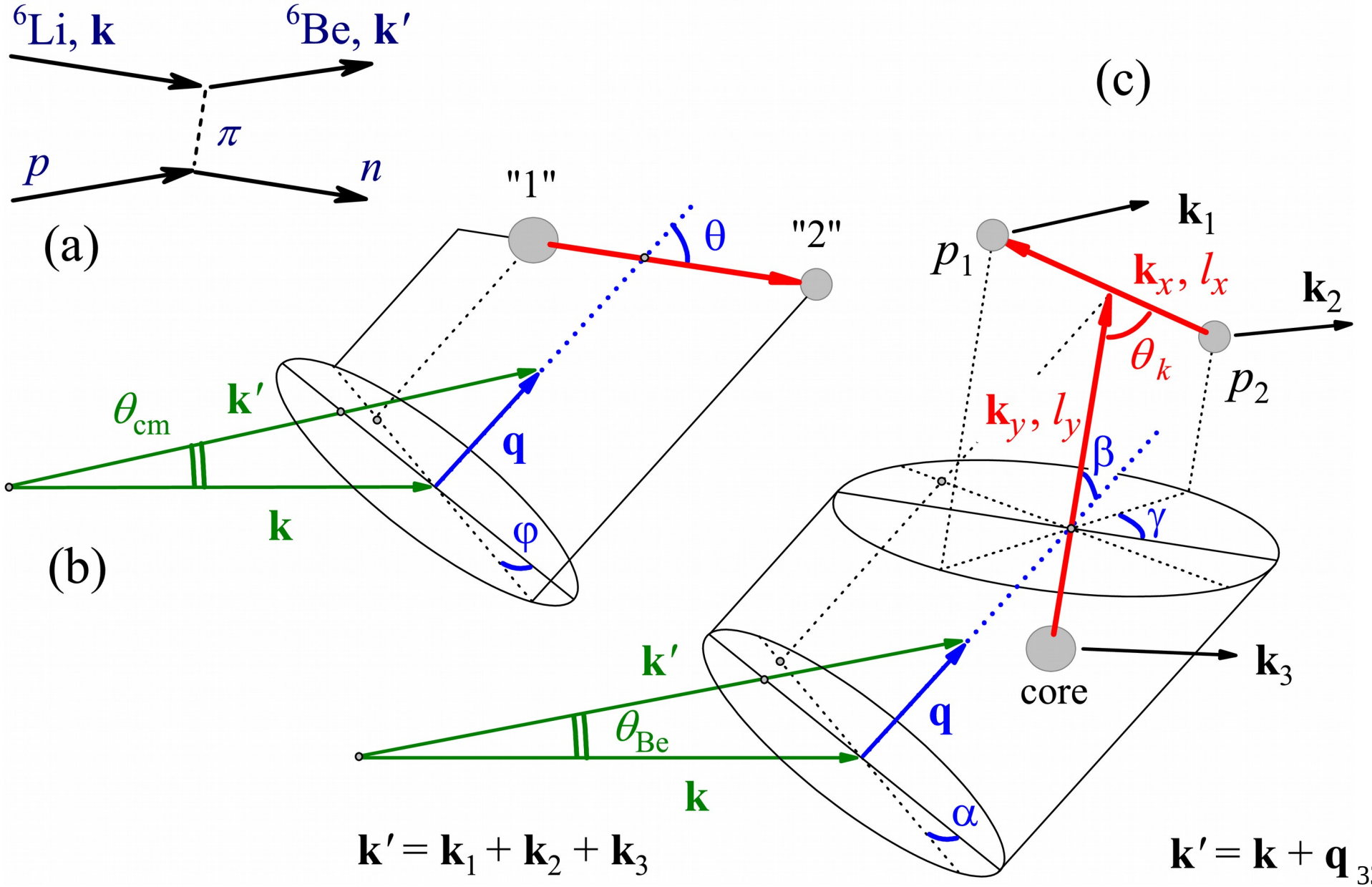
full kinematics measurement

- ^{6}Li beam: 35 MeV/A; 10^{7} pps
- ^{1}H gaseous target: *d* = 4 mm; *p* ~ 3 bar; *T* ~ 35 K
- 3-particle (α and 2p) coincidences

Appendix: Reaction and decay kinematics



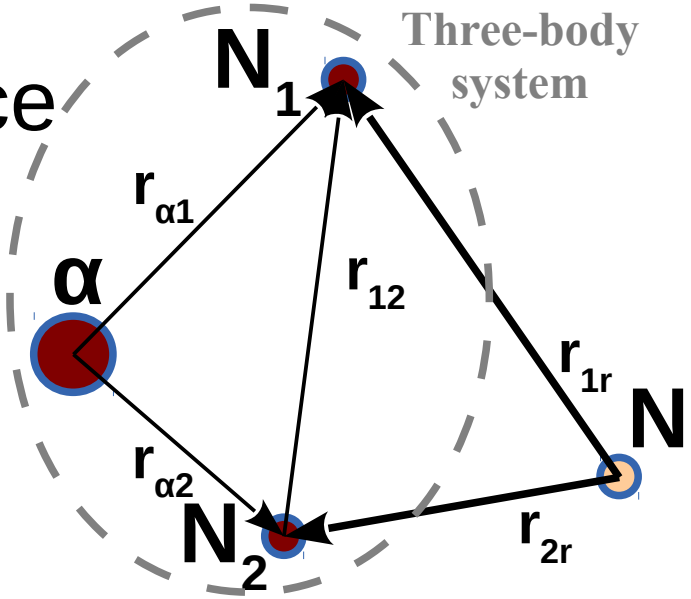
Appendix: Correlations



Appendix: Theoretical model

- Schroedinger equation with source

$$(\hat{H}_3 - E_T)\Psi^{JM(+)}_{^6\mathrm{Be}} = \hat{\mathcal{O}}_{\mu'\mu}\Psi^{J^{(\mathrm{in})}M^{(\mathrm{in})}}_{^6\mathrm{Li}}$$



- information on population of ^{6}Be from ^{6}Li transition operator

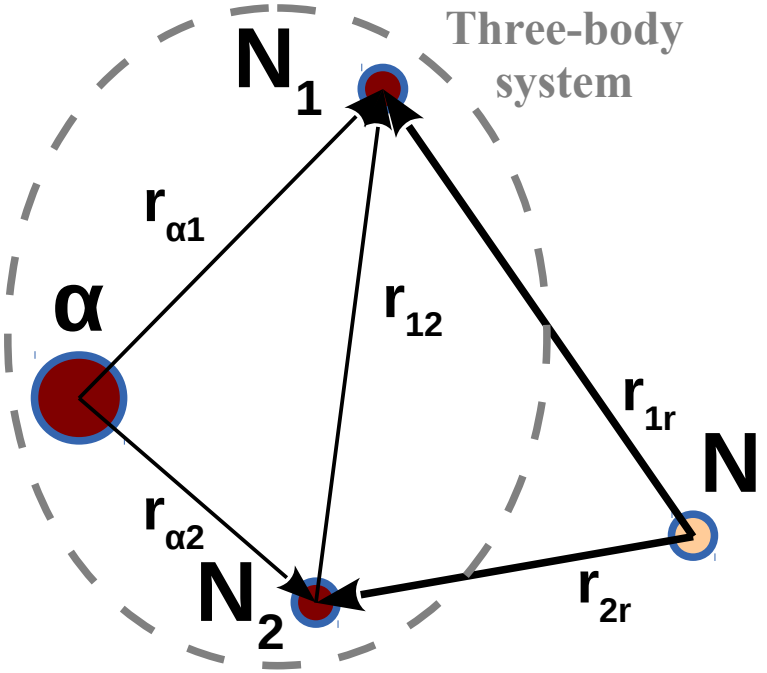
$$\hat{\mathcal{O}}_{\mu'\mu} = \sum_{i=1,2}\sum_{lm} f_l(q,r_i)Y_{lm}(\hat{r}_i)Y^*_{lm}(\hat{q})\ \tau^{(i)}_- \sum_{\nu}(-1)^{\nu}\sigma^{(i)}_{\nu}C^{\frac{1}{2}\mu'}_{\frac{1}{2}\mu 1\nu}$$

- analytical form of transition operator thanks to the choice of the N-N potential used in PWIA

$$\hat{V}_{ir}(r_{ir}) \quad = \quad (\boldsymbol{\sigma}_i\cdot\boldsymbol{\sigma}_r)(\boldsymbol{\tau}_i\cdot\boldsymbol{\tau}_r)\ V_0\exp\left[-\left((\mathbf{r}+\mathbf{r}_i)^2/r_0^2\right)\right]$$

Appendix: Theoretical model

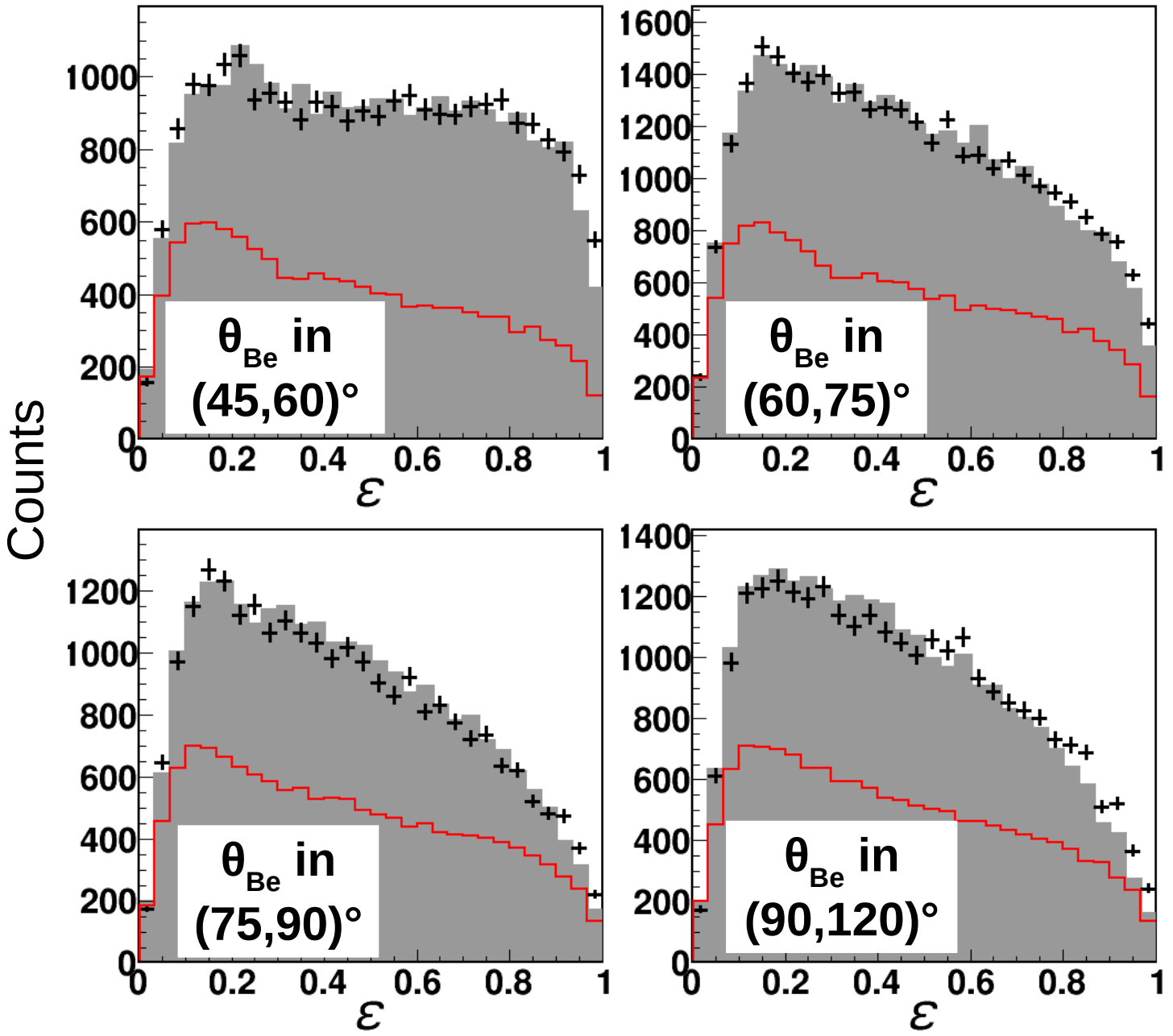
Differential cross section:



$$\frac{d^7\sigma}{dq\,dE_T\,d\Omega_{\varkappa}} = \sum_{SM_S}\sum_{JM,J'M'} \rho_{JM}^{J'M'}(q,E_T)$$

$$\times A^{\dagger}_{JMSM_S}(E_T,\Omega_{\varkappa})\,A_{J'M'SM_S}(E_T,\Omega_{\varkappa})$$

Appendix: Right slope of 2^+



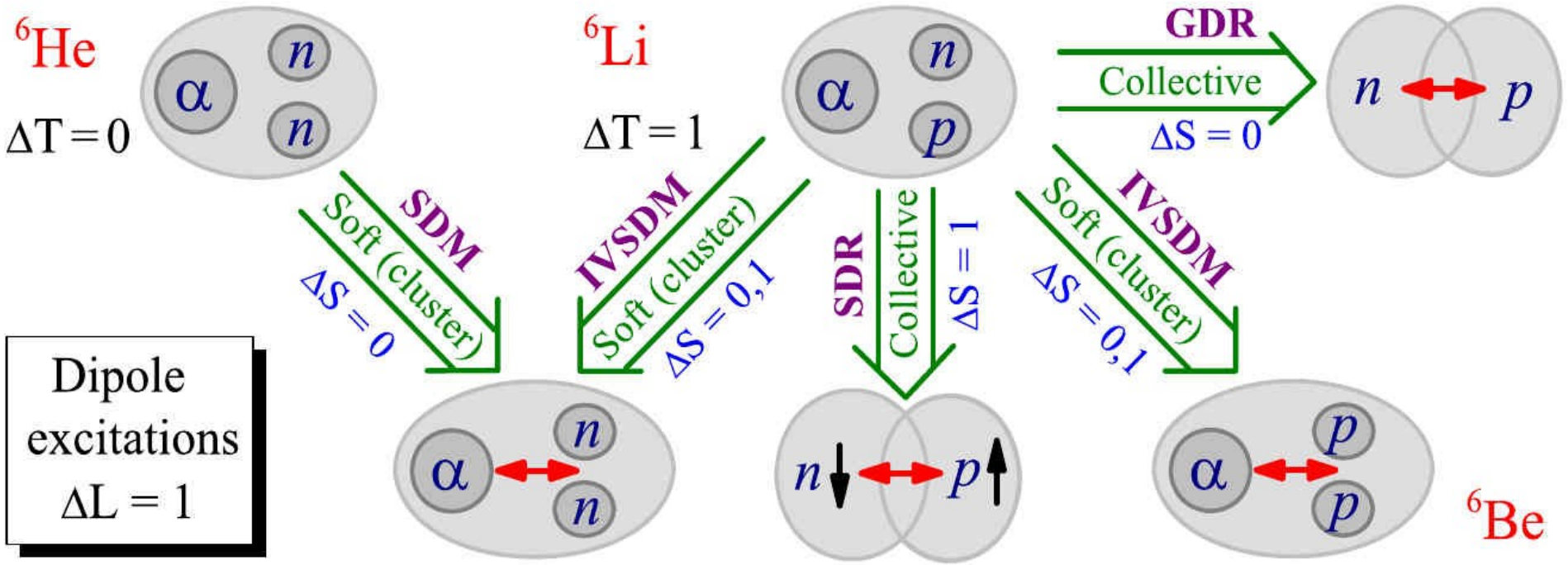
E_T in (2.5,3.1) MeV

strong contribution of 0+

Appendix: Best fits

E (MeV)	(45,60)°	(60,75)°	(75,90)°	(90,120)°
1.4 - 1.9	AL; 135 deg	AL + 50% NA; 180 deg	AL; 180 deg	AL + 20% NA; 180 deg
1.9 - 2.5	NA + 10% AL; 135 deg	NA + 10% AL; 180 deg	NA; 180 deg	NA + 10% AL; 90 deg
2.5 - 3.1	NA + 10% AL; 180 deg	NA + 30% AL; 180 deg	NA + 20% AL; 180 deg	NA; 135 deg

Appendix: Dipole modes



resonance **vs.** **mode**

- property of particular nucleus
- its population does not depend on reaction mechanism

- characteristic for specific reaction
- its population is given by reaction mechanism